Mission Overview

Soil Moisture Active Passive (SMAP) Mission

http://smap.jpl.nasa.gov

Jared Entin

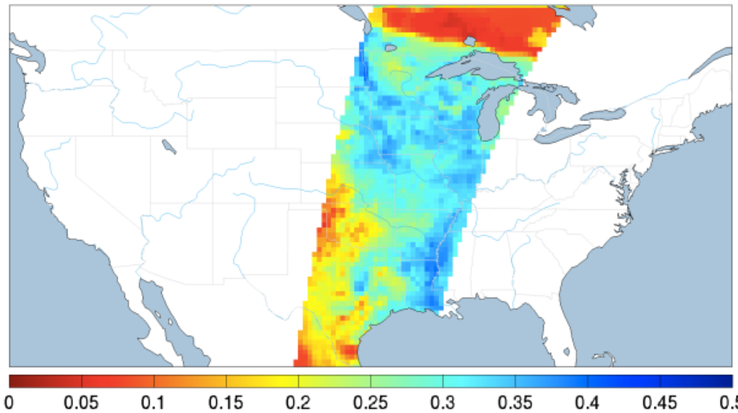
November 10, 2010

National Aeronautics and Space Administration

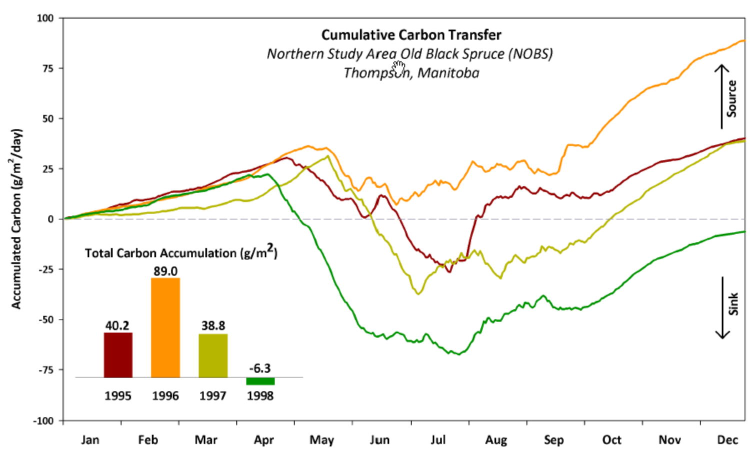
National Aeronautics and Space Administration

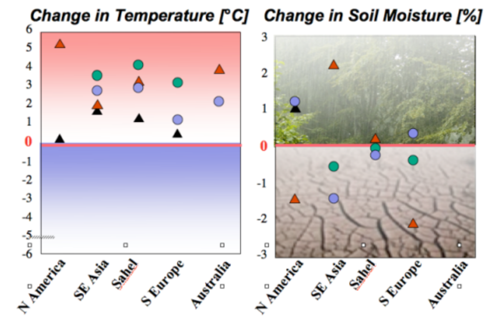
SMAP Completed Initial Mission Formulation; NASA Established a Target Launch Date of November 2014

SMAP will use a rotating 6-m deployable mesh antenna shared by an L-band radar & radiometer to map soil moisture at 10 km resolution and its freeze/thaw state at 3 km resolution globally every 2-3 days

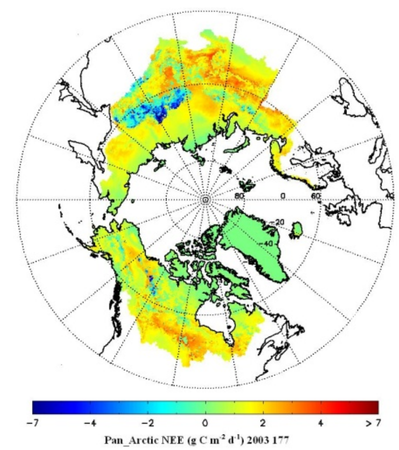


% vol. soil moisture





Improved climate models



Carbon Storage Estimate

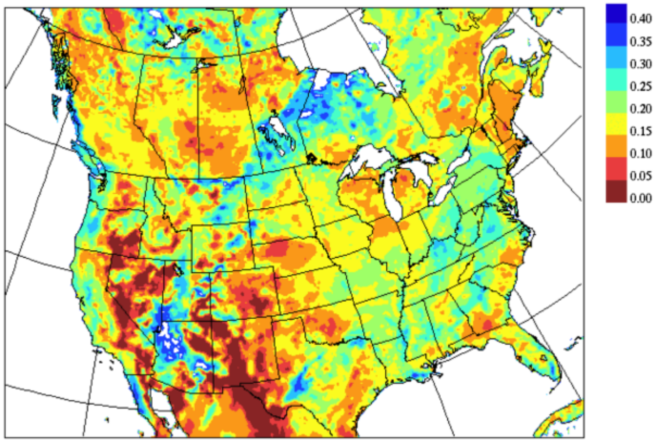
Science Objectives

SMAP will provide high-resolution, frequent-revisit global mapping of soil moisture and freeze/thaw state to enable science and applications users to:

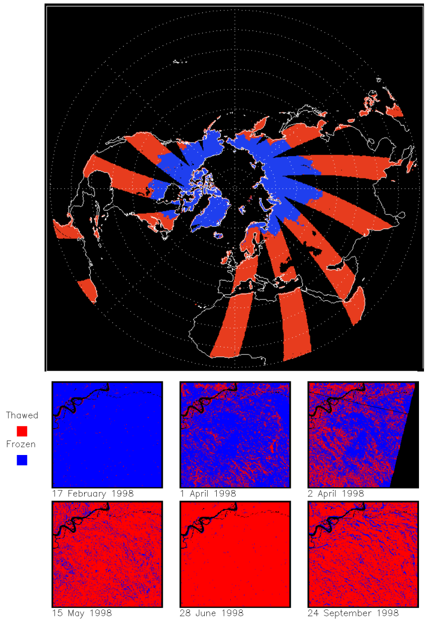
- **Understand processes that link the terrestrial water, energy and carbon cycles**
- **Estimate global water and energy fluxes at the land surface**
- **Quantify net carbon flux in boreal landscapes**
- **Enhance weather and climate forecast skill**
- **Develop improved flood prediction and drought monitoring capability**

SMAP data will also be used in applications of societal benefit that range from agriculture to human health.

Near surface soil moisture



Freeze/thaw state



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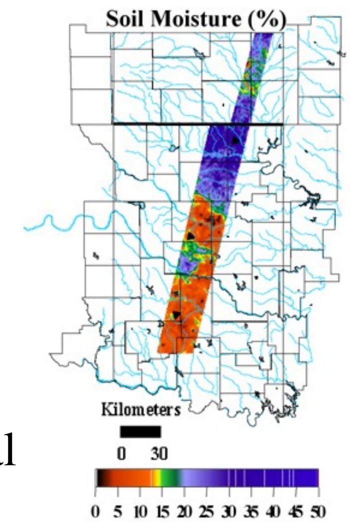
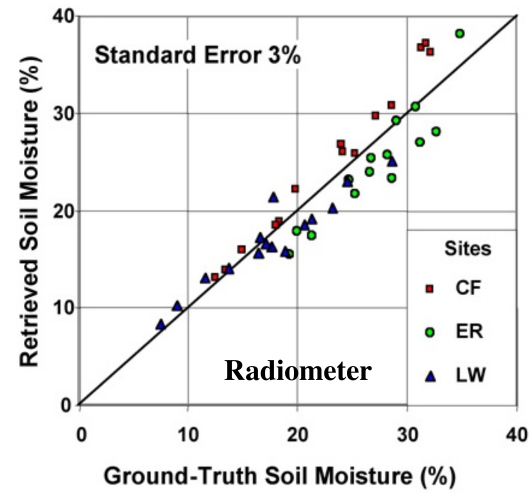
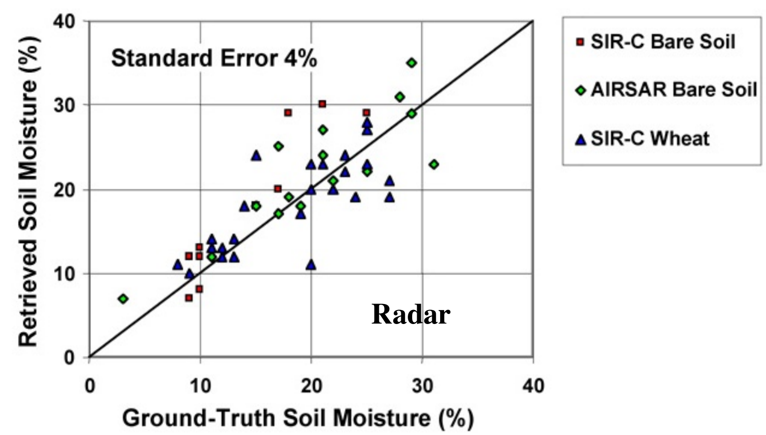
L-band Active/Passive Measurement Concept & Heritage

- Soil moisture retrieval algorithms are derived from a long heritage of microwave modeling and field experiments
  - MacHydro'90, Monsoon'91, Washita'92, FIFE, HAPEX, SGP'97,'99, SMEX'02–'05, SMAPVEX'08
- **Radiometer**—High accuracy (less influenced by roughness and vegetation) but coarser spatial resolution (40 km)
- **Radar**—High spatial resolution (1–3 km) but more sensitive to surface roughness and vegetation
- **Combined Radar-Radiometer** product provides optimal blend of resolution and accuracy to meet science objectives
- Algorithm approach demonstrated in risk-reduction (Hydros); OSSE published (Crow et al. 2005); development extended in SMAP Testbed simulations and field campaigns







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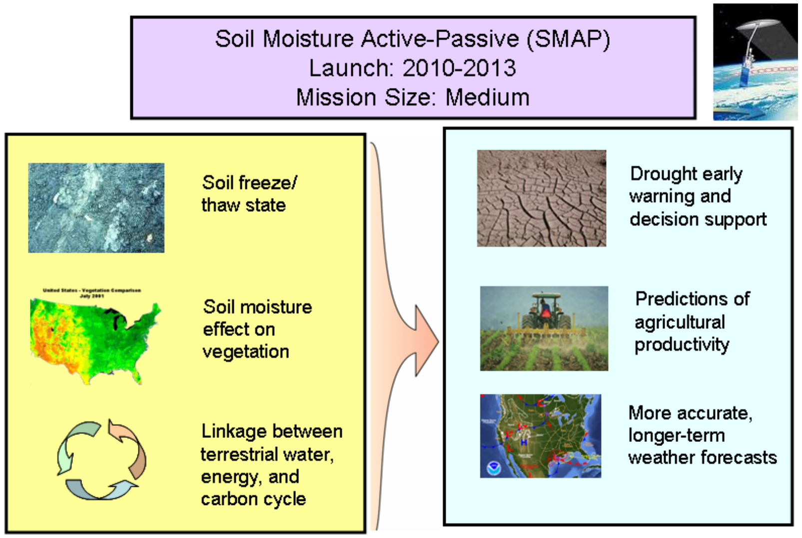
Level 1 Science Requirements Derivation



- SMAP is unique because its measurements would have applications across wide range of Earth sciences and their applications
- Five (of six) disciplinary Decadal Survey panels cite SMAP applications

Decadal Survey Panels #	Cited SMAP Applications
1. Water Resources and Hydrological Cycle	1. Floods and Drought Forecasts 2. Available Water Resources Assessment 3. Link Terrestrial Water, Energy and Carbon Cycles
2. Climate / 3. Weather	1. Longer-Term and More Reliable Atmospheric Forecasts
4. Human Health and Security	1. Heat Stress and Drought 2. Vector-Borne and Water-Borne Infectious Disease
5. Land-Use, Ecosystems, and Biodiversity	1. Ecosystem Response (Variability and Change) 2. Agricultural and Ecosystem Productivity 3. Wild-Fires 4. Mineral Dust Production

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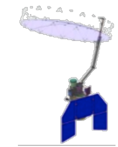
Science Level 1 Requirements



	Science Discipline Measurement Need			Level 1 Science Measurement Requirements			
				Baseline Mission		Threshold Mission	
	Hydro-Meteorology	Hydro-Climatology	Carbon Cycle	Soil Moisture	Freeze/Thaw	Soil Moisture	Freeze/Thaw
Resolution	4–15 km	50–100 km	1–10 km	10 km	3 km	10 km	10 km
Refresh Rate[1]	2–3 days	3–4 days	2–3 days	3 days	2 days	3 days	3 days
Accuracy[2]	4–6%	4–6%	80–70%	4%	80%	6%	70%

Mission Duration Requirement:
3 Years Baseline; 18 Months Threshold

(1) 2 day refresh for north of 45N latitude
(2) % volumetric soil water content (1-sigma) ; % classification accuracy (binary Freeze/Thaw)

Derived From Models and Decision-Support Tools Used in Areas of Application Identified by Decadal Survey for SMAP

DS Objective	Application/Discipline	Science Requirement
Weather Forecast	Initialization of Numerical Weather Prediction (NWP)	Hydrometeorology
Climate Prediction	Boundary and Initial Conditions for Climate Models	Hydroclimatology
	Testing Land Surface Models in General Circulation Models	
Drought and Agriculture Monitoring	Seasonal Precipitation Prediction	Hydroclimatology
	Regional Drought Monitoring	
	Crop Outlook	
Flood Forecast	River Forecast Model Initialization	Hydrometeorology
	Flash Flood Guidance (FFG)	
	NWP Initialization for Precipitation Forecast	
Human Health	Seasonal Heat Stress Outlook	Hydroclimatology
	Near-Term Air Temperature and Heat Stress Forecast	Hydrometeorology
	Disease Vector Seasonal Outlook	Hydroclimatology
	Disease Vector Near-Term Forecast (NWP)	Hydrometeorology
Boreal Carbon	Freeze/Thaw Date	Freeze/Thaw State

SMAP Provides High Returns for Both Science & Applications

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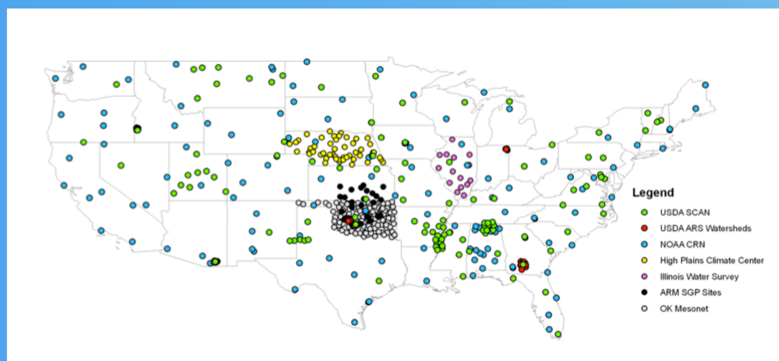
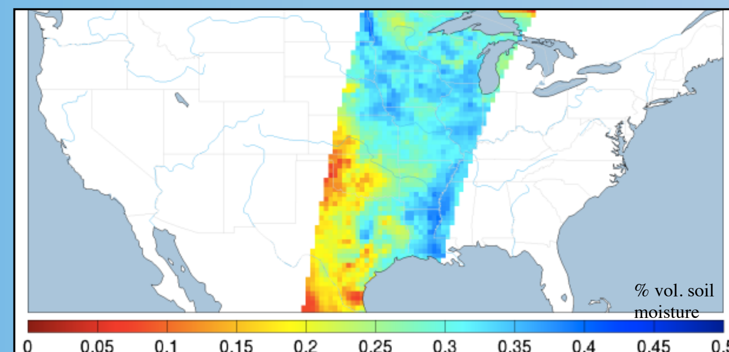
Science Returns

Soil Moisture Links the Global Land Water, Energy, and Carbon Cycles

Current limitations:
- Installed in situ network has inadequate coverage
- Existing space-borne sensors have inadequate sensitivity & resolution

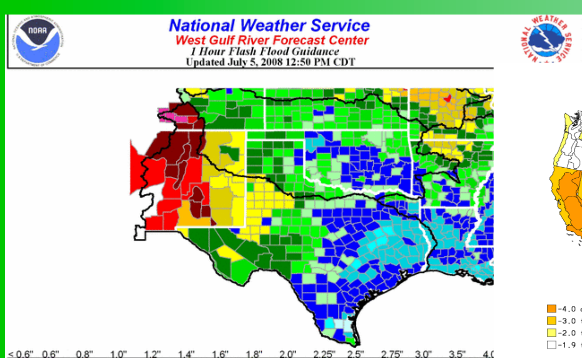


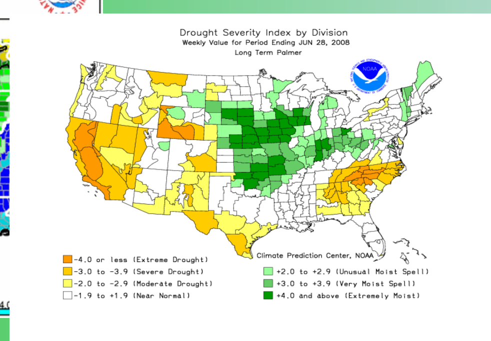
SMAP's 1000 km wide swath maps global surface soil moisture with high revisit (2-3 days)



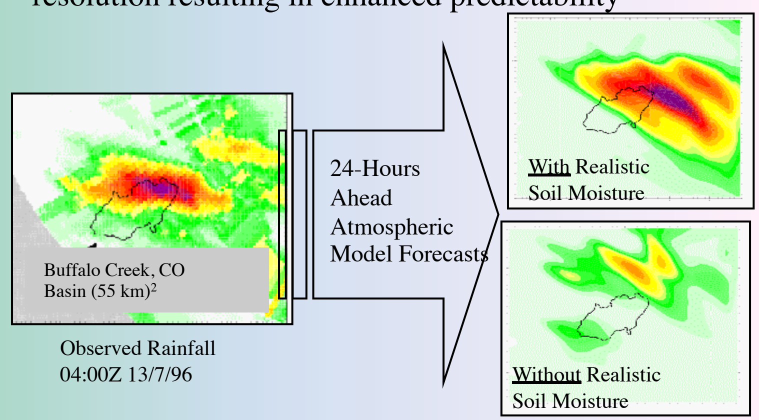
Applications Returns

Current operational flood-guidance and drought-monitoring products use model estimates of soil moisture





SMAP radar and radiometer allow direct estimates of surface soil moisture at an order of magnitude higher resolution resulting in enhanced predictability



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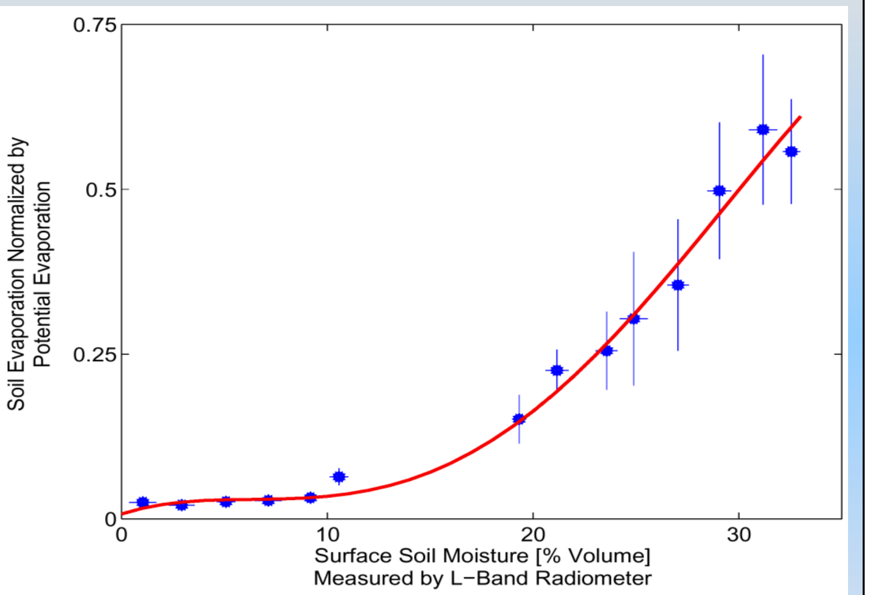
SMAP Data Are Vital for Climate and Global Change Science

SMAP Science and Data Products Address Priority Science Questions on Climate and Climate Change

Water and Energy Cycle

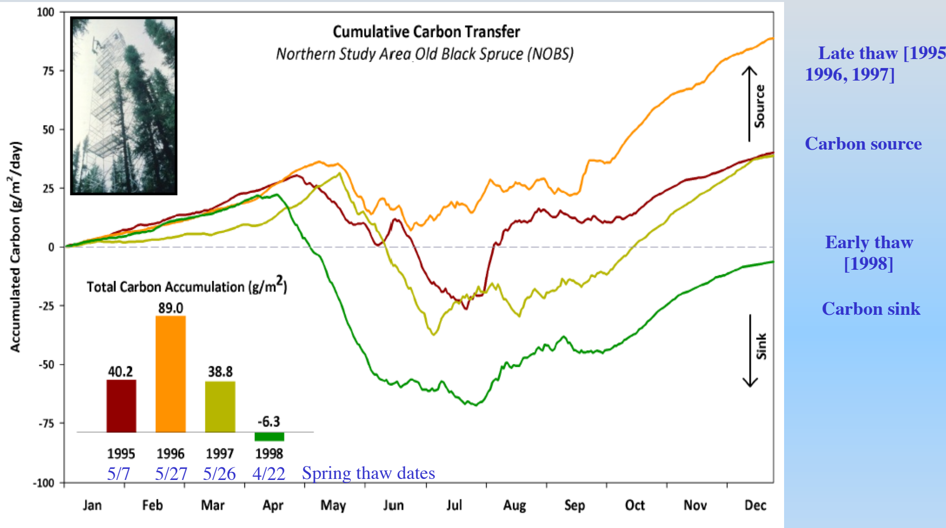


Soil moisture <u>controls</u> the rate of land flux of water and energy to the atmosphere

Do climate models correctly represent the land-surface control on water and energy fluxes?

What are the regional water cycle impacts of climate variability and climate change?

Carbon Cycle



Landscape freeze/thaw dynamics <u>drive</u> boreal Carbon balance [The *Missing-Carbon* problem].

Are Northern land masses sources or sinks for atmospheric Carbon?

How sensitive is the regional carbon cycle to climate variability and climate change?

SMAP Provides Data to Test Model Forecasts of Future Water Availability

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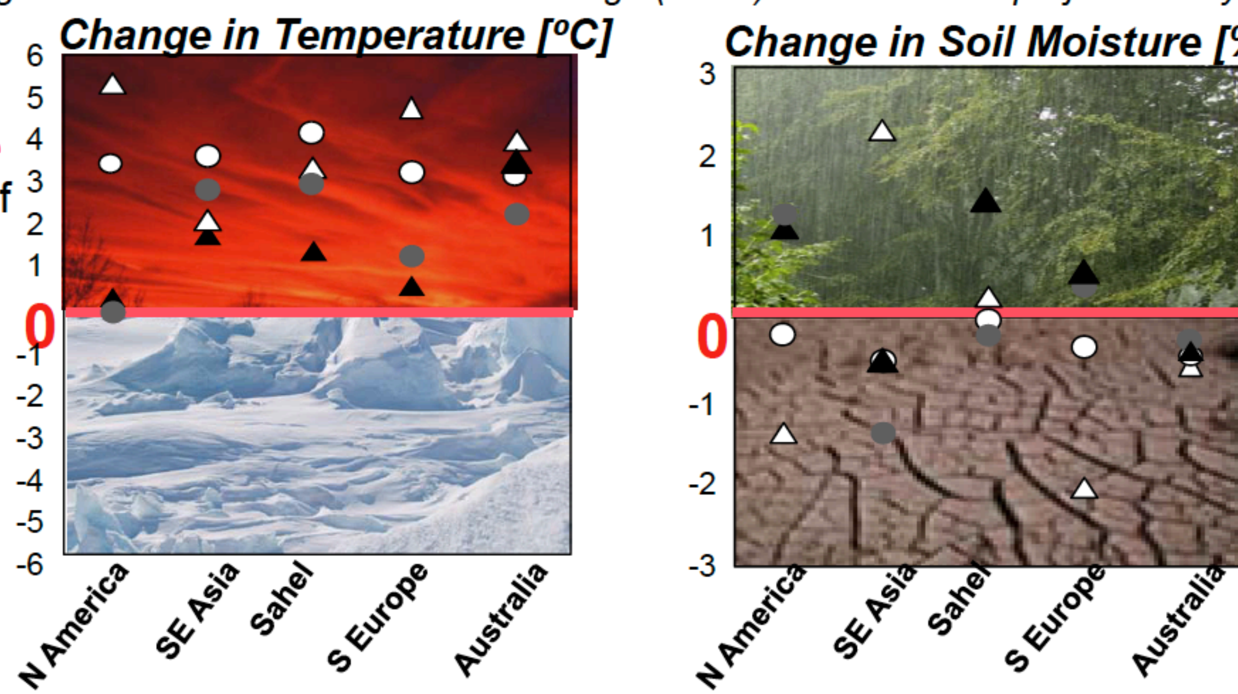
Changes to water availability are a critical practical impact of global warming on society. How will global change affect water supply and food production?

Intergovernmental Panel on Climate Change (IPCC) climate model projections by region:

Models *agree* on direction of temperature increase



Models *disagree* on whether there will be MORE or LESS water compared to today

Without SMAP data we cannot tell which hydrology models are accurate. With SMAP data we will be able to make reliable determination of future changes in available water.

Li et al., (2007): Evaluation of IPCC AR4 soil moisture simulations for the second half of the twentieth century, *Journal of Geophysical Research*, 112.

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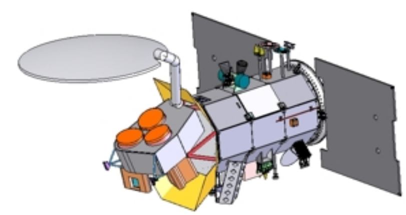
Synergistic Data, Experience from SMOS & Aquarius Reduces SMAP's Science Risk

- SMAP complements SMOS and Aquarius:
  - Extends global L-band radiometry beyond 2015 (yields long-duration land hydroclimate soil moisture datasets)
  - Significantly increases resolution of soil moisture data
  - Adds characterization of freeze thaw state for carbon cycle science
  - Adds substantial instrument and processing mitigations to reduce science degradation and loss from terrestrial RFI
- SMAP benefits from strong mutual science team members' engagements
  - SMOS & Aquarius data are important for SMAP's algorithm development
  - SMAP will collaborate in and extend SMOS & Aquarius Cal-val campaigns
  - SMOS and Aquarius will provide valuable data on the global terrestrial RFI environment and for SMAP to validate RFI mitigation features.
- Long-term availability of data allows application users adoption of NRT products

SMOS (ESA)
2009 Launch

Aquarius
2011 LRD



SMAP
2014 LRD

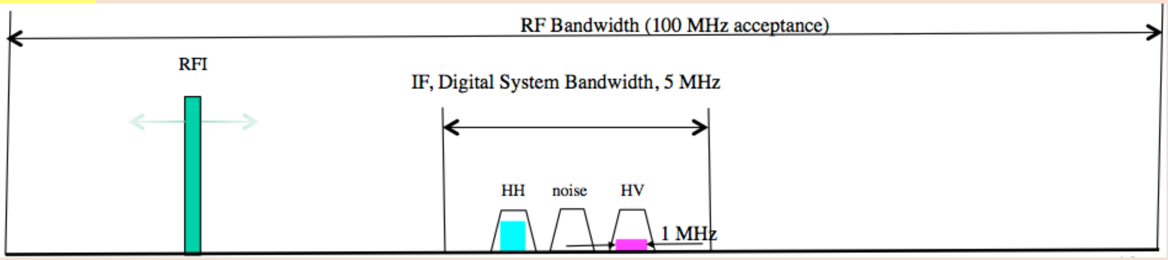
Mission	LRD	Measurement	Instrument Complement	Resolution/Revisit
SMOS	Oct '09	Soil Moisture Ocean Salinity	L-band Radiometer	50 km/3 days
Aquarius	Apr '11	Ocean Salinity Soil Moisture (experimental)	L-band Radiometer, Scatterometer	100 km/7 days
SMAP	Nov '14	Soil Moisture Freeze/Thaw State	L-band Radiometer, SAR (unfocused)	10 km/2-3 days 3 km/2 days (above 45°N)

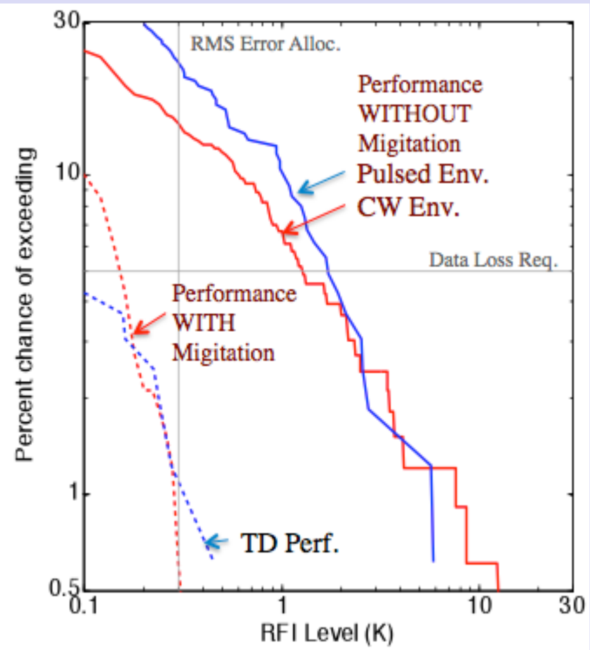
SMAP RFI Mitigation

- Strategy:
  - Survive without damage
  - Detect RFI-contaminated data
  - Avoid RFI (radar only)
  - Remove RFI effects in ground processing

Radar

- Ground-programmable operating frequency allows avoiding known regional RFI sources
- Filtering and dynamic range requirements assure that out-of-band RFI will avoid saturating receiver
- Residual RFI will be detected and removed during science data processing





Radiometer

- Digital spectral filtering enables RFI to be isolated within 16 radiometer subbands
- 4th Stokes is provided to further aid RFI identification
- Successfully demonstrated in Aircraft Tests
- Identification and removal is conducted in ground processing

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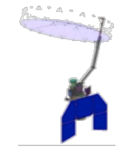

Science Organization

Science Definition Team Leader
D. Entekhabi (MIT)

Project Scientist
E. Njoku (JPL)

Deputy Project Scientist
P. O'Neill (GSFC)

Science Definition Team (SDT) (ROSES)

K. McDonald (JPL)
J. van Zyl (JPL)
R. Koster (GSFC)
R. Reichle (GSFC)
W. Crow (USDA)
S. Moran (USDA)
T. Jackson (USDA)
J. Johnson (OSU)
J. Kimball (UMT)
M. Moghaddam (UM)
J. Shi (UCSB)
L. Tsang (UW)
S. Belair (Canada)

International

P. de Rosnay (UK)
R. Gurney (UK)
Y. Kerr (France)
S. Paloscia (Italy)
J. Walker (Australia)

Applications Coordinator

M. Brown (GSFC)

Algorithm Development Team (ADT)

L2/3_SM_P	S. Chan
L2/3_SM_A	S. Kim
L2/3_SM_A/P	N. Das
L3_F/T_A	S. Dunbar
L4_C	J. Glassy
L4_SM	R. Reichle
Ancillary Data	E. Podest, J. Fisher
Integration	S.Dunbar, S. Chan

Calibration & Validation

A. Colliander (JPL)

Working Groups:
1. RFI
2. Algorithms
3. Cal/Val
4. Applications

Science Organization

Project Scientist
E. Njoku (JPL)

Deputy Project Scientist
P. O'Neill (GSFC)

Science Definition Team Leader
D. Entekhabi (MIT)

**Science Team (ST)
(ROSES)**

The SDT will transition to a ROSES-selected Science Team about 14 months prior to launch

-- SDT focuses mainly on algorithm development and mission / instrument design advice

-- ST focuses mainly on validation of science products

Applications Coordinator

M. Brown
(GSFC)

Working Groups:
1. RFI
2. Algorithms
3. Cal/Val
4. Applications

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(ADT)**

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Calibration & Validation

A. Colliander
(JPL)

Data Products

Data Product Short Name	Description	Data Resolution	Grid Spacing	Median Latency*
L1B_S0_LoRes	Low Resolution Radar σ_o in Time Order	5x30 km (10 slices)	-	12 hrs
L1C_S0_HiRes	High Resolution Radar σ_o on Swath Grid	1x1 km to 1x30 km	1 km	12 hrs
L1B_TB	Radiometer T_B in Time Order	36x47 km	-	12 hrs
L1C_TB	Radiometer T_B	40 km	36 km	12 hrs
L2_F/T_A	Freeze-thaw State	3 km	1 km	24 hrs
L2_SM_A	Radar Soil Moisture	3 km	3 km	24 hrs
L2_SM_P	Radiometer Soil Moisture	40 km	36 km	24 hrs
L2_SM_A/P	Active-Passive Soil Moisture	9 km	9 km	24 hrs
L3_F/T_HiRes	Daily Global Composite Freeze/Thaw State	1-3 km	1 km	36 hrs
L3_SM_A	Daily Global Composite Radar Soil Moisture	1-3 km	3 km	36 hrs
L3_SM_P	Daily Global Composite Radiometer Soil Moisture	40 km	36 km	36 hrs
L3_SM_A/P	Daily Global Composite Active-Passive Soil Moisture	9 km	9 km	36 hrs
L4_SM	Surface and Root Zone Soil Moisture	9 km	9 km	7 days
L4_C	Carbon Net Ecosystem Exchange	9 km	9 km	14 days

* The SMAP Project will make a best effort to reduce the data latencies beyond those shown in this table.

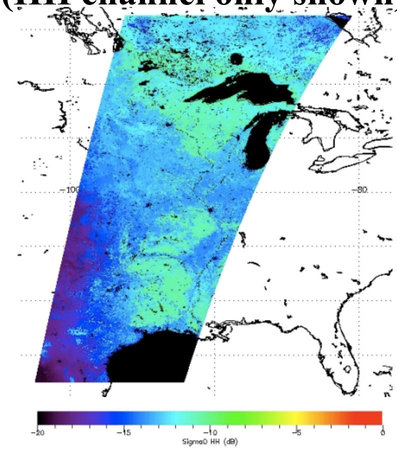
Data Product Status

- Each data product has :
  - an SDT member as a single point of contact.
  - A member of the project team as a point of contact
  - ATBD draft document
  - Algorithm flow plan
  - Ancillary data requirements (incl. risks, e.g. Modis)
- Error analysis underway
  - Driven by SDS (Science Data System)
    - Global sim. – one year
    - US area sim. – multi year
  - Multiple field campaigns of data
  - Use of SMOS data
- ATDB review in Dec 2011
- Final Algorithm down select Sept 2013

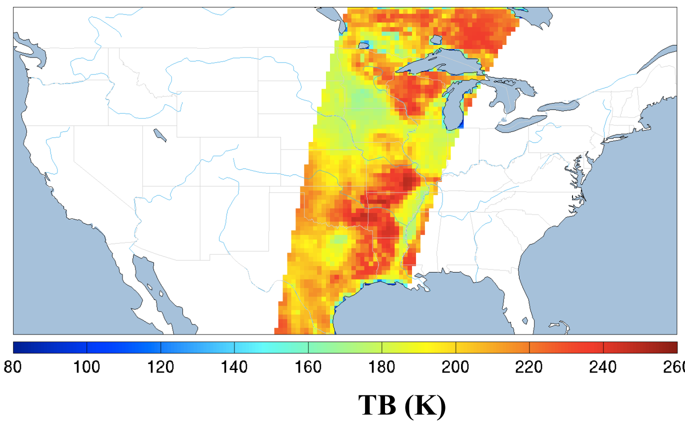
SMAP Prototype Science Data Products

- *Generated with prototype algorithms on the Science Data System Testbed*

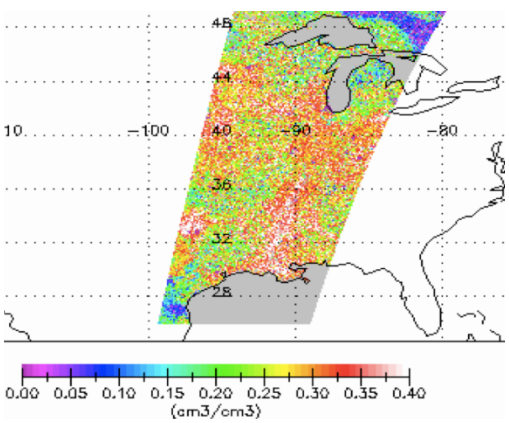
L1C Hi-Res Radar Backscatter Product (1-3 km) (HH channel only shown)



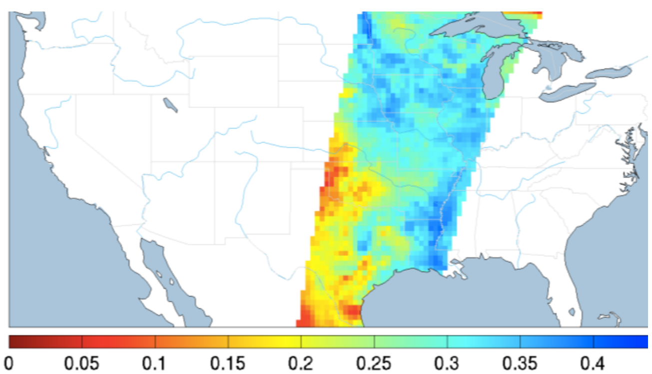
L1C Radiometer Brightness Temperature Product (40km) (H channel only shown)



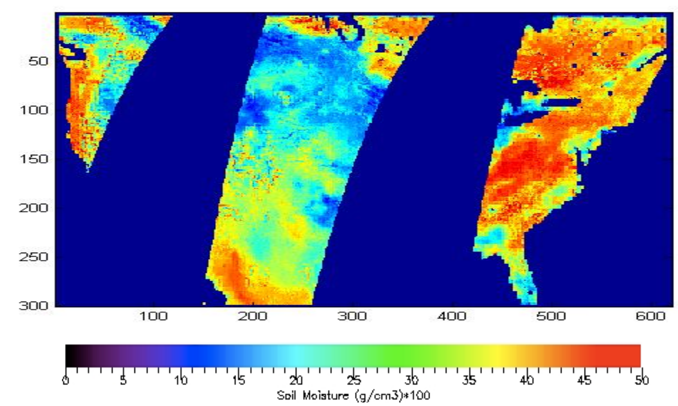
L3 Hi-Res Radar Soil Moisture Product (3 km)



L3 Radiometer Soil Moisture Product (40 km)



L3 Combined Active/Passive Soil Moisture Product (10 km)



SMAP is Engaged w/Community

- **Four SMAP community working groups established for Algorithms, Cal/Val, RFI, and Applications, each led by a SDT member**

- **Recurring community workshops held:**
  - **1st SMAP Algorithms & Cal/Val Workshop: June 9-11, 2009, Oxnard, CA**
  - **1st SMAP Applications Workshop: Sept 9-10, 2009, Silver Spring, MD**
  - **2nd SMAP Algorithms Workshop: March 5, 2010, Wash., DC (after MicroRad 2010)**
  - **2nd Cal/Val Workshop in May 2011**

- **All Decadal Survey missions now required to have increased focus on Applications or Applied Science**

  -- **SMAP Applications Plan (draft) in review at NASA HQ**

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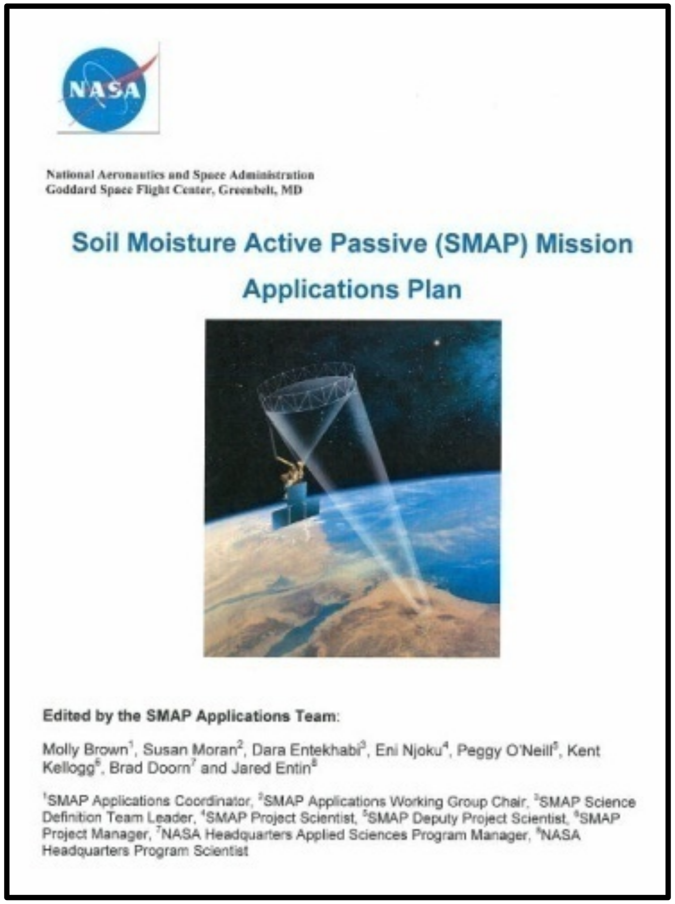
Status of Applications Plan


National Aeronautics and Space Administration
Goddard Space Flight Center, Greenbelt, MD

Soil Moisture Active Passive (SMAP) Mission

Applications Plan

Edited by the SMAP Applications Team:

Molly Brown[1], Susan Moran[2], Dara Entekhabi[3], Eni Njoku[4], Peggy O'Neill[5], Kent Kellogg[6], Brad Doorn[7] and Jared Entin[8]

[1]SMAP Applications Coordinator, [2]SMAP Applications Working Group Chair, [3]SMAP Science Definition Team Leader, [4]SMAP Project Scientist, [5]SMAP Deputy Project Scientist, [6]SMAP Project Manager, [7]NASA Headquarters Applied Sciences Program Manager, [8]NASA Headquarters Program Scientist

- Draft completed, to be on web before PDR
- Preliminary Plan to be completed before CDR
- Two engagement levels:
  - Community of Practice
  - Community of Potential
- Implementation Strategy
  1) Engagement with Early Adopters
  2) Promotion of Community of Potential
  3) SMAP Applications Research, possibly funded by ROSES call
  4) Coordination with SMAP Cal/Val
  5) Coordination with other DS Missions
- Copy of Plan will be posted on SMAP website

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1) Engagement with Early Adopters

What is an Early Adopter?

Early Adopters are defined as those groups or individuals who have a clearly defined need for SMAP-like soil moisture or freeze/thaw data and who have sufficient interest and personnel to demonstrate the utility of SMAP data for their particular application.

Recall that applications are defined as innovative uses of SMAP data products in operational decision-making activities for societal benefit.

Why are we engaging Early Adopters?

To conduct ***pre-launch applications research*** to accelerate the use of SMAP products after the launch of SMAP

How are we engaging Early Adopters?

•MOU (unfunded, immediate)
•ROSES RFP (funded in late 2012)

Memorandum of Understanding with Early Adopters

- Request for nominations through the SMAP AppWG
- Announce the selection criteria and selection team
- Nomination process is submission of 1-page application
    - Description, Approach, Requirements, Milestones & Metrics
- SMAP commitment
    - Provide simulated SMAP data products
    - Provide access to cal/val data
- Early Adopter commitment
    - Conduct applications research
    - Join the SMAP Applications Team
    - Attend SMAP Applications Workshops to report results
- Timeline
    - 2 selections by Jan 2011, 2 by July 2011, 2 by Jan 2012

ROSES RFP (hopefully 2012 through NASA Applied Sciences Program)

- $150K 18-month studies to be completed before the launch of SMAP
- SMAP SDT members will be automatic partners
- Timeline
    - Work out RFP details over next 12 months
    - RFP announced Jan 2012
    - Projects funded October 2012
    - SMAP launch November 2014

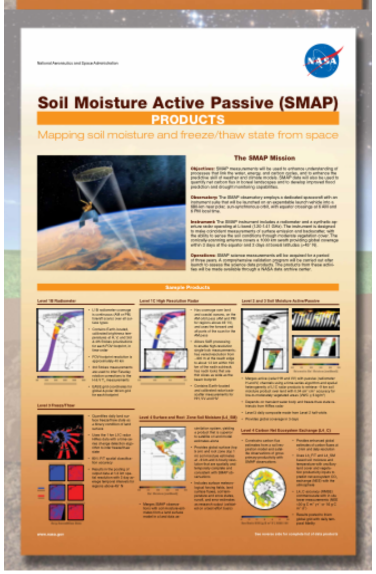
Promotion of Community of Potential

•Communities of Practice and Potential were identified at the 1st SMAP Applications Workshop

• The SMAP Applications Coordinator is working to target more efforts and promote applications from "potential" to "likely"

- SMAP science and applications posters
- SMAP applications powerpoint presentation
- Contacting users in Community of Potential
- Reaching out to international users
- Townhalls at Technical Meetings (e.g., AGU)
- Updates to the SMAP Applications website

•Promote SMAP products as we near launch through articles in Newsletters and Trade magazines



Community of Practice & Community of Potential identified at the SMAP AppWG Workshop

Application	*Comm. Of Practice*	Comm. Of Potential (no contacts, need follow-up)
Weather	AFWA: J. Eylander Am. Univ. Dubai: H. Gheddir EC: S. Belair ECMWF: P. de Rosnay Meteo-France: J-F Mahfouf NCEP: M. Ek NESDIS: X. Zhan NOAA/NWS: L. Friedl & J. Famigletti USACE/CRREL: B. Davis USACE/TEC: M. Tischler USNRL: W. Johnston	NCAR
Natural Disasters	CONAE: M. Thibeault CONAE: M. Thiebualt & D. Dadamia Dartmouth College: Brakenridge DoD: B. Davis FAS/JAWF: H. Shannon GEO/AWCI: Will Possi HRC: K. Georgakokos NIDIS: J. Verdin NOAA/NCEP: M. Ek NOAA/NESDIS/NCDC : J. Bates & M. Brewer NOAA/NESDIS/STAR: X. Zhan NOAA/NIC: P. Colon NOAA/OHD: B. Cosgrove NWS/NCEP: M. Ek USACE/CRREL: B. Davis USAID: C. Stokes & D. Healy USGS: H.. Linns	USCG: [Fritz to followup USBOR [ask D. Toll for name] NOAA/NWS/RFC: [B. Cosgrove to follow-up] FEMA: [B. Cosgrove to investigate]
Climate Variability	ADAGUC: R. de Jeu ECMWF: P. de Rosnay Env. Canada: B. Merryfield & A. Berg	
	JECAM: C. Justice (UM) or J. Fan (GEO) NDMC: M. Hayes NDMC: M. Hayes & T. Tadesse NIDIS: J. Verdin, NOAA/NESDIS: X. Zhan SADC: K. Masasvu Botswana Toshio, U. Tokyo UN/FAO: K. Cressman & J. Bolten USAID: C. Stokes USDA/FAS: C. Reynolds USDA/NRCS: D. Plunk & G. Schaefer USDA/NRCS: G. Schaffer	
Human Health	CDC: K. Gage FAO: M. Cosh & K. Cressman; IRI: P. Ceccato NASA/GSFC: J. Bolten USDA: Wade Crow	[Contact NASA J.Haynes for a list of funded NASA proposals on human health] [T. Jackson will followup with contacts in human health]
Ecology	CarbonTracker: P. Tans CCRS: A. Trichtchenko	[K. McDonald will follow-up with WRI]
Water Resources	CCRS: A. Trichtchenko NASA/GRACE: M. Rodell NASA/GSFC: C. Peters-Lidard, NIDIS: J. Verdin USGS: C. Voss	
Ocean Resources	JAXA: T. Shimada JPL: S.Yueh NASA/GSFC: L. Koenig NOAA/NIC: P. Clemente-Colon NSIDC: W. Meier	
Insurance Sector	RMA: B. Teng & J. Hipple	[B. Teng will follow-up] [Contact B. Gurney for more international applications]

Coordination with SMAP Cal/Val

- SMAP AppWG has been informed of Cal/Val activities & encouraged to participate
- More could be done (i.e., suggestions from the AppWG Workshop):
  - The AppWG could play a role in design of Cal/Val activities
  - The AppWG could serve as a forum to publicize planned field campaigns and attract more involvement from groups interested in SMAP applications
  - The chairs of the SMAP Working Groups could coordinate activities & announcements
- This will be a focus for next year s

CanEX (wet) – June 2010

SMAPEx-1 (winter) – July 2010

SJV (orchards) – Summer 2010

THANKS!

BACK UPs

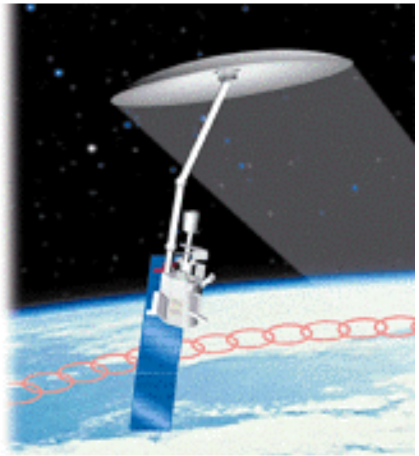
National Aeronautics and
Space Administration

Mission History

SMAP leverages off previous Earth Science projects

Aquarius

- Aquarius project is currently in Phase C (2010 Launch)
  - Sea Surface Salinity Mission
  - Similar partnering arrangement (JPL lead with GSFC supporting)
  - L-Band Radar/Radiometer instrument
- Hydros project discontinued in 2005 due to funding availability
  - Soil Moisture Mission
  - Identical instrument approach: L-Band Radar/Radiometer with 6-meter spinning antenna
  - Professor Dara Entekhabi (MIT) was Principal Investigator (SMAP SDT Lead)
  - Conducted early Phase A risk reduction activities: soil moisture retrieval capabilities studies; antenna stability/performance studies
  - NASA investments in Hydros are directly applicable to SMAP



Hydros